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EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS

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Ottawa

J. A. PEARCE
Head Astronomer
Dominion Astrophysical Observatory
Victoria, B.C.

J. PATTERSON
Controller of the Meteorological Service of Canada, Toronto

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PLATE VII

WHIPPLE'S COMET No. 2

Photographed with a miniature camera with F2.8 lens, focal length 3⅛ in. on March 8-9, 1943; exposure 1 hour.

G. F. Longworth, David Dunlap Observatory.

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COMETS AND METEORS

By A. V. MADGE

(With Plate VII)

LET us look at a comet far out in space as it appears in a telescope. The first view is a hazy patch of light—somewhat like a faint globular nebula. After a period of some hours, the hazy patch of light, it will be observed, has moved slightly in relation to the background of stars in the field of view; a greater distance if viewed the following night, and a much greater distance when viewed several nights later. Gradually, night after night, it becomes clearer and, finally, a wisp of light may be seen trailing away from the ever brightening head until, at last, it becomes visible to the naked eye and we can then readily see through the telescope the three parts into which comets have been divided: the *nucleus,* or bright centre; the *coma,* or gaseous envelope surrounding the centre; and the *appendage,* or *tail,* sweeping far out into space from the head in the direction opposite the sun.

During the observation of a comet, it will be seen that the head, or coma, varies in size. Further, all comets are not of the same size. The average size is from 30,000 miles to 150,000 miles in diameter; a few being even larger. Halley's comet, when first observed in 1910, had a diameter of 14,000 miles, yet later, when much nearer the sun, the diameter of the head rose to approximately 300,000 miles. But when actually at its nearest to the sun the diameter of the head fell temporarily to less than 60,000 miles. This temporary diminution in size when a comet is at its nearest to the

sun is a common occurrence. In the middle of the coma there is usually a central nucleus of more intense light. This nucleus may have a diameter of only a few hundred miles. The length of a comet's tail is even more variable than the diameter of the head. If the tail is visible to the naked eye it is usually not less than five to ten million miles in length. Many comets have had tails fifty million miles in length, and occasionally the tails have been traced to a distance of nearly 100 million miles from the head. The appearance of the tail varies from comet to comet. Some are almost straight, others curved, others broken, others forked, still others being a mixture of these forms. Changes may occur in a comet's tail from one hour to the next.

Direct photography has shown that the material in the tail of a comet is travelling outwards from the head, always away from the sun, with a velocity that is continually increasing. This proves that the material is moving under the influence of a continually acting force emanating from the direction of the sun, and not under some momentarily acting force such as might be supposed to arise from an explosion in the comet's head; for in this latter case the material would be driven out with a constantly diminishing, instead of an increasing, velocity. It appears that the material in a comet's head first moves towards the sun because of gravitational attraction. The lighter particles separate from the larger and their forward velocity is gradually diminished and finally reversed by the sun's radiation pressure, the particles being so minute that the radiation pressure is greater than the sun's gravitational attraction. There must be some inherent force within the nucleus of the comet itself because all the forward motion of the material in the comet's head cannot be accounted for by the sun's gravitational influence alone. That such an inherent force can exist is revealed by the spectroscope. Donati, in 1864, was the first to examine a comet with the spectroscope. The light of the comet was seen to consist of three bright bands—blue, green and yellow—separated by dark intervals. The light was thus largely emitted by the comet itself and not light from the sun reflected by it. Huggins, in 1868, examined another comet spectroscopically. He showed that the bright bands in the spectrum of the comet were identical with those emitted by certain hydro-

carbons when excited in a vacuum tube by an electric discharge. The first photographs of a comet's spectrum, in 1881, fully confirmed the origin of the bright lines from compounds of hydrogen and carbon, but they showed also the presence of a continuous spectrum crossed by dark lines—a replica of the solar spectrum. This was the first indication that, in addition to emitting light of its own, a comet shone by reflecting sunlight. Present-day spectroscopic studies reveal that practically all comets give the typical bands due to compounds of carbon and hydrogen, carbon and oxygen, and of carbon and nitrogen. It seems to be the normal rule, when a comet gets very near the sun, for the bands of the carbon compounds to fade out and be replaced by the bright lines of sodium vapour.

As a comet approaches the sun it brightens up very much more quickly than can be accounted for by its diminishing distance from the sun. There is no doubt that this is due to some influence exerted by the sun which causes the comet to emit, as it nears the sun, radiations of rapidly increasing intensity. Probably, and this is a personal opinion, what is observed is a phenomenon created by electrical induction. All chemical action creates electrical discharges; all electrical discharges cause a more or less pronounced degree of luminosity when they pass through and excite gases in a vacuum tube. The matter which comprises a comet's head, and more particularly that which comprises a comet's tail, is in a particularly vacuous state. It would seem that the luminosity of a comet not directly attributable to reflected sunlight must be caused by some form of fluorescence. Occasionally, in certain comets, the tail has undergone rapid distortion in shape. This distortion cannot be accounted for by radiation pressure alone. Some of the distortion may be caused by a stream of meteors passing through and disrupting the comet's tail. A personal opinion is that there may be electrical forces at work by which the particles in the tails of certain comets repel one another. This opinion would account for the so-called fan-shaped and broken comet tails. A close examination of photographic plates seems to reveal that particles in the tails of all comets repel one another, but not all to the same extent. Streams of electrons emitted by the sun may have much to do with the phenomena which occur during the visible life of a comet.

And from whence do comets come? Astronomers have been trying to answer that question for many years. Different theories have been advanced. One is that comets have been accidentally swept up by the solar system during its flight through space. This theory, if correct, would suggest that many more comets ought to meet us than overtake us; that is, they ought to arrive most frequently from that direction in the heavens towards which we are travelling with our sun. Observation shows however that comets arrive indiscriminately from all directions. The theory cannot, therefore, be altogether correct. Another theory was that a gigantic eruption had occurred on the planet Jupiter many ages past; comets being formed from the debris thrown out by this eruption. The reason suggesting this theory is that many comets have orbits which, when most distant from the sun, come very close to the orbital path of Jupiter. The theory seems to ignore the velocity which would have to be attained by such debris to escape from a planet of such a mass. The theory is not favoured by most astronomers and the belief has been expressed that the comets belonging to Jupiter's family were captured by Jupiter as a result of its gravitational attraction. All the comets of Jupiter's family revolve round the sun in the same direction as the planets. There would be little chance of Jupiter capturing a comet moving in the opposite direction—the comet and the planet would pass each other too rapidly for the gravitational influence of the planet to seriously affect the comet's path—though the comet's elliptical orbit might be changed to a parabolic or even a hyperbolic curve. On the other hand, when moving together in the same direction the gravitational attraction of the planet Jupiter would have a longer period in which to pull a comet from its original path into a permanently shortened ellipse. It would seem that the capture theory gives a plausible explanation of Jupiter's family of comets and that the eruption theory is false.

It is frequently said that a comet observed moving on a hyperbolic orbit must have come from somewhere outside our solar system. I cannot subscribe to this reasoning. Comets, *when we see them*, might be moving in elliptical, parabolic, or hyperbolic orbits. An elliptical orbit is closed and comets moving in such an orbit must return to the sun at regular intervals. Parabolic and hyperbolic

orbits are open at their far ends and, thus, it would seem that any comets seen moving in such an orbit could pay only a single visit to the sun. It is impossible to distinguish a parabola from an extremely elongated ellipse, or from a hyperbola with a small angle of divergence. It must be admitted that if a comet enters our system on a definitely proven parabolic or hyperbolic path, it must have come from outside our system. There is still no proof that any comet has ever entered our system on either of these paths. Eight comets which did definitely pass around the sun in hyperbolas were investigated by Professor Strömgren of Copenhagen. He found that, in each case, the path was not originally hyperbolic, but rather that each comet had had its hyperbolism thrust upon it. In each case there had been a close encounter with a planet during the inward journey to the sun, and this had brought about the conversion of an originally elliptical orbit into a hyperbolic path. It is a personal opinion that we might very readily lose a comet from our system, but doubts must be expressed on whether we ever gain a comet from outside it. Until there is conclusive evidence of a comet having entered the solar system along a hyperbola, it must be assumed that comets are all original members of the solar system and travel invariably in ellipses, until the elliptical orbit is changed by the gravitational influence of one of the planets, being either shortened, lengthened, or changed into a parabolic or a hyperbolic path.

For the present we shall leave comets and discuss meteors. According to Dr. Peter M. Millman of the David Dunlap Observatory, "Meteors are small fragmentary particles of iron or stone, the debris of space, which, on entering the earth's atmosphere at high velocity, ignite and are in general completely vaporized." Upon rare occasions the body of the meteor is so large that the vaporizing process is not entirely completed before the meteor falls to the earth's surface. Those that do fall and are found are called meteorites. It has been estimated that approximately ninety per cent. of the original mass of a meteorite is fused away during its flight through our atmosphere and that only ten per cent. of the original body reaches the earth in compact form. It is believed that thousands of tons are being added to the earth's mass each year through the settling of the meteoric dust thus formed.

Meteorites have been classified into three groups:

1. Siderites (metallic or iron meteorites)
2. Aerolites (stony meteorites)
3. Siderolites (intermediate or stony-iron meteorites)

The siderites are constituted mainly of iron alloyed with from 5 to 10 per cent. of nickel. They also contain traces of manganese, phosphorus, sulphur, platinum and chlorine. The chlorine causes them to be quickly destroyed by the oxygen of our atmosphere should they fall in a moist climate. This is the reason that iron, the most abundant of earth's metals, never occurs on the earth's surface as a metal as in siderites or siderolites, but always in ores as an oxide. When siderites are machined smooth, polished and etched with a weak acid they show, as distinguishing features, the beautiful crystalline Widmanstatten figures. Commercial iron does not show these figures. A crystallized steel-grey iron-nickel phosphide found only in meteorites is named *schreibersite*. A transparent calcium sulphide occasionally found in meteorites is named *oldhamite*. These minerals are practically unknown in the earth's crust since they cannot exist long in the presence of oxygen and moisture.

Aerolites contain about seventy-five per cent. of magnesium and iron silicate which is known as *olivine*; this olive-green variety of chrysolite or arsentiate of copper occurring in prismatic crystals and also in reniform (kidney-shaped), granular, and fibrous crusts, is found in certain earth rocks. All aerolites show surfaces of thin dark or grayish, more or less perfect, glass formed by fusion of the various constituents from heat generated during passage through our atmosphere, giving the meteorite a crusted, vitreous appearance.

Siderolites from their very nature of being part siderite and part aerolite, generally contain the elements common to both. Siderolites generally are composed of a spongelike network of nickel-iron alloy together with the other elements found in siderites, the interstices being filled with the stony material found in aerolites. No meteorite has ever been found that consisted of the sedimentary or metamorphic rocks common to earth such as limestone, marble, shale, sandstone, or slate, nor any unchallenged trace of vegetable life, fossilification being entirely absent.

Meteorites range in size from a grain of sand to boulders weighing

many tons. The Grootfontein meteorite, found in South West Africa some years ago and weighing at least fifty tons, presently carries the distinction of being the world's largest discovered meteorite. The Greenland meteorite now in the American Museum of Natural History and weighing thirty-six tons is the largest siderite on exhibition.

And from whence do meteors come? It is now commonly accepted by most authorities that there is a close relationship between comets and meteors and the theory that meteors result from the disintegration of comets is too well supported to be lightly brushed aside. The theory is generally accepted because the great showers of meteors always seem to occur when the earth intersects and crosses the orbits of comets. Biela's comet, which for many years had been a visitor having a period of roughly six and two-thirds years, was last seen in August 1852. On the night of November 27, 1872, as the earth crossed the orbit of Biela's comet, a dazzling display of meteors was observed. This shower was again observed in 1885 and in 1892, and it now seems that the meteors seen regularly each year around November 27th and known as the Andromedes are the remnants of Biela's comet.

Other co-relations of this kind are:

Shower	*Maximum Date*	*Related Comet*
Lyrids	April 21	Thatcher (1861-I)
Eta Aquarids	May 4	Halley's
(Pons-Winnecke)	June 28	Pons-Winnecke
Perseids	August 12	Swifts (1862-III)
Draconids	October 9	Giacobini's
Leonids	November 16	Tempel's (1866-I)
Andromedes	November 27	Biela's

It is now assumed that comets are only temporary bodies which sooner or later must break up into smaller comets or disintegrate into star dust or into showers of meteors which may be observed by earth dwellers only when their orbit and that of the earth intersect. It would seem only logical to accept the theory advanced by Professor Daniel Kirkwood of Indiana who said "Meteors and meteoric rings are the debris of ancient and disintegrated comets whose matter has been distributed around their orbits." It appears that

comets which are now pursuing their orderly way through our solar system throw off, and leave in their wake, streams of meteors which continue to follow the same orbit as that of their parent body. It is now generally supposed that the nucleus of a comet is composed of meteoric material, glowing with an incandescent heat resulting from collisions, or luminous from some sort of electrical action; the true cause of the luminosity of comets not yet having been satisfactorily proved.

All meteors belonging to annual showers have real velocities that never exceed 26.2 miles per second. By real velocities is meant the true velocities after taking into consideration and allowing for the earth's orbital velocity of 18.5 miles per second. The observed velocity of a meteor is clearly its velocity relative to the earth. If a meteor is overtaking the earth directly from behind, it is necessary to add eighteen and a half miles a second to its observed velocity. If a meteor meets the earth head on, the eighteen and a half miles per second must be subtracted. Similar corrections must be made for a meteor arriving from any angle between the two extremes, straight ahead or straight behind. The earth's parabolic velocity is 26.2 miles per second and it has been said that if a meteor is observed moving at a faster real velocity, it must be a chance visitor from outer space, and not originally a member of our solar system. A personal opinion is that this reasoning is open to argument. The possibility exists that a fast moving meteor *arriving from outer space* may have been left in the wake of a comet which, though formerly a member of our system, had its elliptical orbit changed to a parabolic or hyperbolic path of small divergence through the gravitational influence of one of the larger planets of the solar system. In such case the meteor would have originated within our solar system even though *it had returned to us from outer space*. This suggestion does not deny the possibility of a chance meteor coming to us from the region of some other sun far out in the depths of space—it does infer the margin of chance to be slight. Let us examine this inference. The British Astronomical Association Handbook for 1922 gives a radiant for every night of the year. The Memoirs of the Royal Astronomical Society, volume 53, lists 1000 meteor radiants. This large number of annual meteor showers has been definitely

detected. A large number of observed meteors, however, appear to be quite independent bodies, showing no communal tendency to radiate from any particular point in the sky. These are known as *sporadic meteors*, or when they appear in groups as *sporadic showers*. It would seem that there are far too many of these sporadic meteors smashing into our atmosphere for them to have come to us by mere chance; particularly when there is so much free space for them outside that small portion occupied by our sun and our neighbouring planets—our solar system is, after all, comparatively a mere grain of dust in an ocean of space. Many of these sporadic meteors travel at a real speed in excess of 26.2 miles per second, far too many of them. It is highly improbable that we should have so many chance visitors from other distant systems. In fact, according to a quite recent hypothesis, few if any other systems such as our solar system exist in our galaxy of stars. This hypothesis affirms that certain definite conditions must exist and certain definite accidents must occur before any star could have a family of planets accompanying it through space. The chance of these conditions and these accidents happening simultaneously is so remote that we may accept the statement that there are few, if any, planetary systems existing in our galaxy other than our own. Can a star without planets, it might be asked, have a family of comets and meteors?

An opinion has been advanced that meteors may have been formed directly from the sun at the same time as the planets, being the material that was, so to speak, left over. There may be vast scattered quantities of this left over material throughout and extending to the outermost region of our solar system. With this in mind, let us consider a personal hypothesis. Let us suppose that comets are but one phase of a definite cycle. Let us suppose that meteors are another, possibly a more permanent, phase of that cycle. The theory has been expressed that comets are constantly disintegrating into swarms of meteors. Let us suppose that comets are constantly being formed within our solar system; comets formed from meteors—the debris of earlier comets. And how would this come about? The simple, understandable word "collision" might give the answer, a collision between two different meteor swarms, or between a meteor swarm and an asteroid. The effect of the collision being the produc-

tion of what we know as a comet which gradually returns to its pre-collision meteoric state within our solar system or, because of the gravitational attraction of a large planet, is pulled from its regular elliptical orbit into a parabola or a hyperbola and forever lost to us—except for those meteors which, travelling at a real speed of more than 26.2 miles per second, return to us from outer space. The supposition, therefore, is that meteors, being the debris left over after the formation of a planetary system, cannot exist without a planetary system and that no star being without a planetary system can have a family of meteors and comets. The acceptance of these suppositions leads to the conclusion, *that comets and meteors, all of them, have their origin within our solar system.*

Let those of us who accept this conclusion do so, for the present, with an open mind and a strong desire to learn the ultimate truth.

5175 Cote St. Luc Road,
Montreal, Quebec.

KIRKWOOD'S GAPS IN THE ASTEROID ORBITS*

By John J. DelGrande and Sidney V. Soanes

IN 1866, Professor Daniel Kirkwood[1, 2] of the University of Indiana pointed out that the divisions in Saturn's rings were due to perturbations caused by its satellites, the action of Mimas being especially strong; and he further showed that there were gaps in the asteroid belts. These gaps occur at distances from the sun such that an imaginary asteroid travelling in one of the gaps would have a period of revolution which would be a simple fraction of that of Jupiter.

About 1917, Percival Lowell[3] continued this investigation, and, like Kirkwood, concentrated his attention on the divisions in Saturn's rings of which there were now about seven or eight known. He also applied the theory to the asteroids with considerable success, but their number was not sufficient to give very extensive results. He stated: "If the asteroids were numerous enough we should actually behold in the sky a replica of Saturn's rings, altered only by the perspective of our different point of view." Professor Kiyotsugu Hirayama[4] of the Tokyo Imperial University has done some interesting work along similar lines (1918-23). He was more concerned with grouping the asteroids into families, assuming that each "family" had a common origin. By January 1923, 14 per cent. of the known asteroids had been quite definitely grouped thus, and another 16 per cent. were slightly doubtful. In his later papers, Professor Hirayama did not appear especially concerned with the actual gaps, although the earlier ones were mostly on the distribution of the mean motions of the asteroids. He gave an inter-

*This paper originated from an exercise taken by the class in the astronomical laboratory of the III year Mathematics and Physics course at the University of Toronto.

[1]*The Asteroids*, Daniel Kirkwood.

[2]Smithsonian Annual Report for 1876, p. 358.

[3]Astronomical Journal, v. 26, p. 171; *Ibid.* v. 27, p. 41; Memoirs of the Lowell Observatory, v. 1, no. 2.

[4]Annales de l'Observatoire Astronomique de Tokyo, Appendices no. 6, 8, 9, 11.

esting explanation of the gaps on the basis of resisting particles moving about the sun in circular orbits.[5]

As a simple case illustrating the mathematical theory behind these perturbations, consider an asteroid whose period is one half that of Jupiter. For every revolution of Jupiter about the sun, there will be two positions of minimum distance between Jupiter and the asteroid, and these positions will always be the same. Consequently the asteroid will always suffer perturbations at the same places, with the result that its mean distance from the sun gradually alters so that the ratio of the periods is no longer the simple fraction, one-half.

A number of years have elapsed since any new statistical investigations of the distributions of the asteroids have been published. At the time when Kirkwood discovered such gaps there were only about 80 known asteroid orbits; *Kleine Planeten* for 1940, listed 1489 such orbits. A frequency curve of the semi-major axes of these orbits has been plotted, as shown in figure 1.

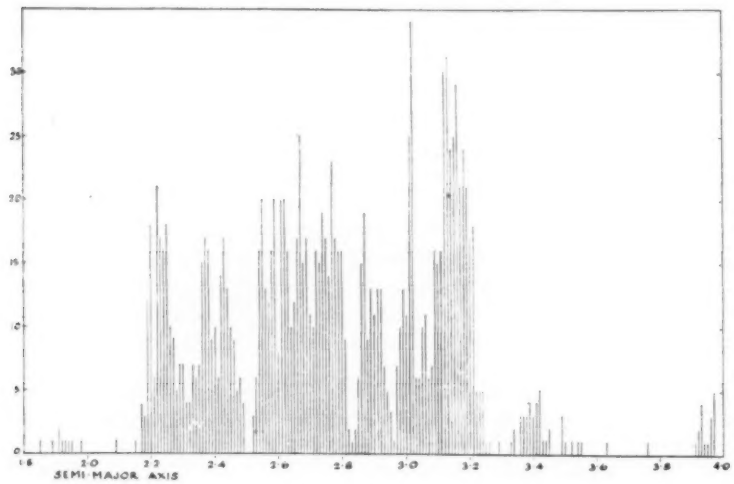

Fig. 1.—Frequency curve of the semi-major axes of 1474 asteroid orbits.

[5] *Ibid.* no. 2.

The following asteroids have not been included in the diagram:

1. Eros ($a = 1.46$ A.U.)
2. One asteroid whose $a = 4.25$ A.U.
3. Twelve asteroids of the 'Trojan Group'; $a = 5.09$ to 5.23 A.U.—approximately the same distance from the sun as Jupiter.
4. One asteroid whose $a = 5.80$ A.U.

The relation between the mean distance a, of any planet and the period, P, is given by Kepler's third law which states that $P^2 = k\,a^3$, where k is some constant. Therefore it is a quite simple matter to compute the period of an imaginary asteroid travelling in one of the gaps. Our method is somewhat different from that of Lowell or Hirayama. They both chose arbitrary commensurate periods and tried to fit them to the gaps. We calculated the periods corresponding to the a's of the gaps, and then found the ratios of these periods to those of other planets. In this way periods commensurate with those of Jupiter, Saturn, and even Mars were discovered. Professor Hirayama, in grouping the asteroids into families, has indirectly accounted for some of the gaps; but it seems more likely that the asteroids were originally distributed according to the laws of probability, and disturbances caused by the other planets over a period of millions of years have arranged them as they are now.

The following table lists the principal gaps and shows the relations between the period of an asteroid at this distance and the periods of Jupiter, Saturn and Mars.

The most conspicuous feature of the diagram and table is that the chief gaps occur at distances for which the asteroid periods would be simple ratios of the period of Jupiter. The table shows all the gaps that would be expected and several smaller ones, some of which unfortunately are somewhat doubtful. About ten times as many asteroids would give more reliable results.

Bode's law calls for a planet at a mean distance of 2.8 A.U. Interestingly enough this is very close to one of the most conspicuous gaps; but on the other hand, the greatest peaks in the asteroid grouping come at 2.67, 2.77, 3.02 and 3.13 A.U., while only a comparatively small number of asteroids are known with a less than 2.4 or greater than 3.2 A.U.

a	P	$P_{♃}/P$	$P_{♄}/P$	$P/P_{♂}$	Remarks
1.99	2.81	4:1	10:1	3:2	A very wide gap; also $P=3P_{⊕}$
2.08	3.00				
2.10	3.04			5:3	
2.15	3.14				
2.21	3.28		9:1	7:4	A very narrow deep gap
2.31	3.53	4:3			*
2.41	3.71		8:1	2:1	*
2.50	3.95	3:1			A very pronounced gap; also $P=4P_{⊕}$
2.57	4.11			11:5	
2.60	4.19		7:1	9:4	
2.64	4.29	11:4			
2.70	4.45	8:3			
2.83	4.77	5:2		5:2	One of the best gaps†
2.88	4.87		6:1		
2.96	5.09	7:3			
3.04	5.28	9:4			A very deep gap
3.07	5.38	11:5			*
3.17	5.64			3:1	
3.28	5.93	2:1	5:1		A very pronounced gap
3.56	6.71	5:3	4:1	4:1	
3.90	7.62				
4.00	8.00			9:4	Also $P=8P_{⊕}$

Note: a and P are given in terms of the earth as unity.

*There is some doubt about these gaps.

†Note also $P_{♄}/P_{♃}=5:2$. See *Old and New Astronomy*, Proctor and Raynard, pp. 559-562.

In examining the list of asteroids one notices that there are quite a number with periods of revolution very nearly equal to that of Jupiter. This suggests a theory which, while not original, is seldom discussed—that the outer satellites of Jupiter are captured asteroids. This explains the retrograde motions and high inclinations of these outer satellites; and although the two outermost ones are very faint, it is possible that one of the reasons they were just recently discovered (Nicholson, 1938) is that they have been associated with their primary for a relatively short time. In figure 2 is shown what might happen. An asteroid A with an orbit of semi-major axis slightly smaller than that of Jupiter will also have a slightly smaller periodic time, Thus it will gradually

overtake Jupiter, at the same time being pulled slightly out of its orbit. At each successive conjunction, it will pass closer to Jupiter and with lower relative velocity. Under certain conditions the gravitational force of the planet would be great enough for the asteroid to be pulled completely out of its normal orbit and to revolve about Jupiter as another satellite. In the diagram the motion of the satellite will be retrograde. The orbit of such a satellite would initially be very eccentric, and only if the celestial

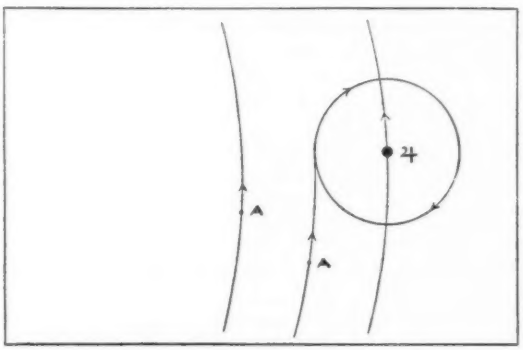

Fig. 2.—Diagram to explain the action of Jupiter on a near by asteroid.

latitude of the asteroid and of Jupiter were the same would the orbit be parallel to the plane of the ecliptic. This could explain the high inclinations of the orbits of some of Jupiter's satellites. With adequate data and ample mathematical knowledge one should be able to calculate just when Jupiter would acquire another moon—thus having one's name go down in the history of astronomy along with those of Tycho Brahe and Percival Lowell.

OUR EARTHLY FLIGHT

by
W. Carl Rufus

Our Earth is like a transport plane,
That carries wealth surpassing gold.
It trafficks not for paltry gain:
Its cargoes are not bought nor sold.

It holds its course around the sun:
Nor rolls, nor banks, nor stalls, nor spins.
Its yearly flight is never done;
When winter ends, the spring begins.

At eighteen-miles-per-second speed
Without an instrument in sight,
No stick to hold, no maps to read,
It travels on by day and night.

It bears a load of human freight;
From birth to death, men come and go.
They live and love, they toil and hate,
For good or ill, for weal or woe.

A billion walk its crowded ways:
And billions sleep beneath its sod.
But souls are safe through stormy days:
The unseen Pilot's name is God.

OBSERVATIONS OF VENUS, 1938-42, AND THEIR INTERPRETATION

By W. H. Haas and H. M. Johnson

Concluded from page 152

Russell has proved[6] that the well-known prolongation of the cusps by the planet's atmosphere is caused by the diffuse reflection of sunlight. It hence follows that if R is the radius of Venus and ϕ the angular breadth of the twilight-arc as seen from the centre O of the planet, then the height h of the reflecting layer is given by:

$$h = R\,(\sec\phi - 1), \tag{1}$$

as is easily shown. Since R is known, we need only have ϕ to compute h. We shall develop an approximate formula for finding ϕ from the angular perimeter p of the illuminated portion of the disc. We shall assume that the atmosphere is of the same nature all around the planet so that the angular separation σ of the observed terminator from the "theoretical" terminator, the one which an atmosphereless Venus would have at an infinitely great distance from the sun, is constant. For an atmosphereless planet at dichotomy one has:

$$p = 180^\circ + \tau, \tag{2}$$

where τ is the angular diameter of the sun as seen from the apex of the planet's shadow. Since at dichotomy there is observed unforeshortened at each cusp an arc caused by the finite distance of the sun, it follows that the portion of σ due to this cause is $\tau/2$, and hence:

$$\sigma = \phi + \tau/2. \tag{3}$$

The amount l by which each cusp is lengthened is given by:

$$l = (p - 180^\circ)/2. \tag{4}$$

Let us denote by C a point above one of the "theoretical" cusps and at a distance $R + h$ from O, by C' the corresponding actual cusp, and by P the base of an arc dropped from C normally upon the actual terminator. These three points determine a spherical triangle. Now, $\overset{\frown}{CP} = \sigma$, $\overset{\frown}{CC'} = l$, $\angle C'PC = 90^\circ$, and $\angle CC'P$ is nearly equal to i if $i < 90^\circ$ and is nearly equal to $180^\circ - i$ if

$i > 90°$. (If $i = 90°$ equation (5) derived below will still apply.) By spherical trigonometry:

$$\frac{\sin \widehat{CP}}{\sin \angle CC'P} = \frac{\sin \widehat{CC'}}{\sin \angle C'PC};$$

or

$$\sin \sigma = \sin i \sin l,$$

and finally, by (3) and (4):

$$\sin (\phi + \tau/2) = \sin i \sin \{(p - 180°)/2\}. \qquad (5)$$

This approximate relation differs from the one developed by Russell,[6] which was derived for very large values of i and is not valid near dichotomy, near which time many of our group's measures were made. For Venus $\tau/2 = 0°22' = 0°.4$. The use of an approximate formula is fully justified by difficulties encountered in observing p. When i is below about 60° the cusps are not sharply enough defined to permit p to be measured. When i exceeds about 100° the ends of the horns are so thin and faint that they tend to disappear when haze or bad seeing is present, difficulties growing more pronounced as the planet approaches inferior conjunction and is seen against an increasingly brighter background.

We have at hand four independent determinations of ϕ:

1. Haas made 25 sets of micrometric measures of p with i between 63° and 138°, inclusive, at Case and at Ohio State; reduced by (5), these yield:

$$\phi = 2°.6 \pm 0°.3.$$

2. Thirteen sets of micrometric determinations of p carried out by Spangenberg in 1937 while i ranged from 82° to 132° and sent to us by him give:

$$\phi = 6°.8 \pm 0°.9.$$

In these measures the individual ϕ's computed by (5) show a marked correlation with i.

3. We have at hand 28 observations of p in 1937, 1940, and 1942 which consist either of visual estimates made at the telescope or of subsequent measures of drawings made there. Suitable weights were given to the individual observations. The mean and its probable error are:

$$\phi = 3°.8 \pm 0°.2.$$

4. In 1938 Haas twice employed an indirect micrometric method. If b denotes the linear distance from the middle of the limb to a point midway between the cusps and d the linear distance separating the cusps, then near dichotomy it is approximately true that:

$$\phi + \tau/2 = \tan^{-1}(2b/d - 1). \qquad (6)$$

The reduction by (6) of the two measures gives as the mean:

$$\phi = 4°.5.$$

We finally want to choose a mean value $\bar{\phi}$ on the basis of these four determinations. Since it is evident that the probable errors assigned three of them have very slight significance, it appears likely that systematic errors have affected each one. To minimize the effect of such errors we shall weight each determination equally and obtain:

$$\bar{\phi} = 4°.4.$$

It is not easy to state how accurate $\bar{\phi}$ is, but we consider it probable that the true value lies between 2°.0 and 6°.0. More and better observational determinations of ϕ are needed. Perhaps one can best get them through numerous micrometric measures of p when i is very large with large telescopes in a sky as clear and dark as possible; and through photographs.

Russell has concluded from a study of observations of p at very large values of i that our ϕ is 1°.1[6]. This smaller value than ours may be at least partly due to the invisibility of the ends of the horns on the brilliant sky near the sun. A further cause may be the failure of the assumption about the uniform nature of the atmosphere made when (5) was derived and also made by Russell. As i increases from 90° toward 180°, the solar rays which illuminate C' cross the "theoretical" terminator at increasingly greater distances from C. We shall see that the atmosphere along the terminator grows less clear as one moves away from a cusp-cap. When i becomes *large enough* the solar rays that would be expected to illuminate C' are unable to do so, and the C' seen is necessarily lit by rays crossing the "theoretical" terminator nearer to C. The corresponding reduction in p leads to smaller computed values of ϕ.

We shall denote by D the angular distance between the actual position of the middle of the terminator and the place where this point would be if Venus lacked an atmosphere, calling D positive if it is such as to increase the "breadth of phase" and negative otherwise. This D has been determined as follows:

1. If Venus lacked an atmosphere the "breadth of phase" would be half the "diameter" when i equalled 90°.4. We hence obtain from the value of i_3 deduced above:

$$D = -3°.5 \pm 0°.6.$$

This result will be assigned a weight of three.

2. Ten sets of micrometric measures of the angular "breadth of phase" by Haas give:

$$D = 0°.1 \pm 1°.9.$$

Deserving little confidence because of bad atmospherical conditions, this determination will be given a weight of one.

3. Haas obtained from measures of some of Wilson's 1940 photographs a value for D of $-3°$ in blue, $-2°$ in green, and $+6°$ in red. We shall take the average to be:

$$D = 0°.0,$$

a rough determination that will be given a weight of one.

4. Haas obtained from measures of some of Wilson's 1941 photographs 11 separate observations of D. It was found possible to combine directly measures of the yellow and the blue images, there resulting:

$$D = -4°.3 \pm 0°.5.$$

The 1941 images are sharper than the 1940 ones, and this value will be assigned a weight of two.

5. Measures by McEwen[5] make the "breadth of phase" at unit distance to be $13''.13$ instead of the theoretical $13''.80$. With $i = 69°$ at unit distance, the deficiency of $0''.67$ becomes about $0''.67/\sin 69° = 0''.72$ when measured along the surface of the planet. Since the angular radius of Venus is $8''.41$ at unit distance, one finds from the proportion:

$$\frac{-0''.72}{2\pi \times 8''.41} = \frac{D}{360°} \tag{7}$$

that

$$D = -4°.9.$$

This value will be given a weight of three.

The weighted mean of the five determinations is:

$$\bar{D} = -3°.4.$$

Here again more and better observations are needed, and a great number of micrometric measures made near dichotomy in good seeing would establish an improved value. We consider it probable that the true value of D lies between $-2°.0$ and $-5°.0$.

It appears at first sight not unlikely that the appearances discussed above and evidently caused by the Venusian atmosphere might vary in different colours. Such attention as has been given to this problem has largely led to negative results. Johnson and Haas have often noticed an apparent reduction in the "breadth of phase" when a blue filter is used, but it is suspicious that it is the least bright portion of the disc which vanishes and that Haas was unable to confirm this result when he used a larger telescope. On Wilson's 1940 photographs the blue images are notably smaller than the red ones, a result contradicting Ross' work on this

problem.[1] If one accepts Wilson's suggestion that his result is due to a redness of the Venusian atmosphere,[2] one is led by computation of the thickness of the atmosphere from the difference in size of the red and blue images to a very unlikely value of about 500 miles. Late in 1940 Haas obtained visually on Venus results like Wilson's photographic ones, using the same filters as Wilson; but Haas also found similar effects on Jupiter and Saturn. The fact that on Wilson's 1941 photographs the yellow images average larger than the fainter blue ones probably means little. It is our conclusion that the suspected effects of blue filters as compared to red filters or no filters are all illusions caused by lessened irradiation as a result of the smaller total transmissivities of the blue filters employed.

We next want to interpret the observational data we have been summarizing. By equation (1), with $R = 3850$ miles[7] and $\phi = 4°.4$, there results:

$$h = 11 \text{ miles.}$$

There is no justification for supposing this h to denote more than the height to which the reflecting layer extends above the visible surface at the terminator in the cusp-regions. It may be objected that we have ignored the possible role of refraction; but Russell has shown that the horizontal refraction on Venus is at most only $0°.2$,[6] a quantity small enough in comparison to the degree of uncertainty of our ϕ to justify our procedure. Considering D to be *negative*, and letting h' denote the height to which the opaque layer of the atmosphere extends above the visible surface at the middle of the terminator, it follows by analogy with (1) that:

$$h' = R(\sec D - 1). \tag{8}$$

With $R = 3850$ miles and $D = -3°.4$, (8) gives:

$$h' = 7 \text{ miles.}$$

If the stoppage of light is abrupt, as at the top of a rising layer of clouds,[8] this value will be the height of such clouds; but if it is gradual, as might occur in a very hazy atmosphere, the obscuring particles may rise to heights considerably exceeding h'. It is apparent by (1) and (8) that h and h' are unfortunately very sensitive to small changes in ϕ and D respectively, and the difference of four miles between them cannot be regarded as significant.

The observed value of i_1 (its difference from 90°) shows that

the atmosphere is not uniformly clear all around the terminator but instead becomes progressively more opaque to the incoming sunlight as one moves from either cusp toward the middle of the terminator. That more localized variations in the degree of transparency of the atmosphere exist is shown by irregularities on the much-prolonged horns when i is very large[9] and by the fact that one cusp sometimes projects more than the other near dichotomy (in March-April 1940 the writers independently remarked the south cusp to project the more).

The quantity i_2 can be used to give a rough check on much of our work, for it is easily shown that it is nearly true that:

$$\frac{\phi + \tau/2}{\sin i_2} = 90° - i_2 + D + \tau/2. \tag{9}$$

With $\phi = 4°.4$, $\tau/2 = 0°.4$, $i_2 = 79°.3$, and $D = -3°.4$ the left side of (9) is $4°.9$; the right side, $7°.7$. It is perhaps worth remarking that increasing i_2 by several degrees would lead to sensible equality.

It has been computed from the thickness of the luminous ring surrounding Venus when it transits the sun that the atmosphere is 50 miles high. The cause of this ring has been attributed to reflection, but we prefer to follow Russell[6] and ascribe it to refraction, for anyone who has seen how faint the lengthened horns are when Venus is close to the sun at very large values of i can scarcely credit that they should remain visible when the planet is projected against the sun and when the light-reducing techniques necessary in visual solar work are applied. The ring must rather be the vastly brighter[6] refracted image of the sun. Russell asserts that a rarefied shell of gases can account for the ring.[7] This refracting layer must be rather clear; it evidently extends all around the terminator and presumably lies above the sunlight-stopping material already shown to exist there.

When Venus occulted η Geminorum on July 26, 1910, Baldet, Quénisset, and Antoniadi independently observed that the star increased rapidly in brightness for 1.5–2.0 seconds after emersion from behind the dark limb.[10] They computed the height of the comparatively clear layer needed to cause this absorption to be 50–70 miles. Their result suggests that the picture of the atmosphere along the terminator which we have presented may be very

untypical of the rest of the planet. Future occultations of stars by Venus should assuredly be ***very carefully observed.***

We shall now consider bright spots reported by some of our group to project beyond the general curve of the limb or the terminator; there is no good reason for doubting that these projections resemble their Martian counterparts in being caused by clouds. Barcroft has observed the terminator to be rough and more or less indented, and Vaughn has recorded minute humps along it. Wilson has seen these aspects. Nevertheless, Johnson has found the terminator to be smooth and not certainly serrated; and though he observed a rough terminator near dichotomy in 1937[11] and has occasionally drawn projecting bright spots on the terminator, Haas has come to doubt the reality of both appearances. We shall venture to conclude from the conflicting evidence that probably some minute irregularities do exist. Irregularities on the limb are still more difficult. Early in 1936 Haas recorded minute bright spots very near to, but apparently detached from, the limb;[12] not having seen them since then, he regards an actual detachment as doubtful. A drawing by Spangenberg on March 31, 1937, makes a bright area on the south limb project. In 1927 Wilson observed what looked to him like a range of mountains on the limb near the south cusp. The ultra-violet photographs by Ross show irregularities on the limb. It is not really certain that any of these apparent limb-projections are more than irradiative effects on bright marks at the limb.

We desire to apply numerical tests to these clouds. If δ is the angular diameter of Venus in seconds, δ' ($=7700$) its linear diameter in miles, β the angular height in seconds of a cloud seen unforeshortened radially, and β' its linear height in miles, then:

$$\beta' = \frac{\delta'\beta}{\delta} = \frac{7700\beta}{\delta}. \tag{10}$$

A cloud seen projecting on the limb or on the terminator when i is far from 90° is seen in profile. Let b signify the angular breadth in seconds of such a projection. Let ω denote the non-obtuse angle between two radii of the spherical planet, the one directed to the earth and the other to the projection. Clearly:

$$\beta = b/\sin\omega. \tag{11}$$

By (10) and (11):

$$\beta' = \frac{7700\, b}{\delta \sin \omega}. \tag{12}$$

A direct application of (12) is prevented by a complete lack of estimates of b. In view of the adverse atmospherical conditions almost always hampering work on Venus it appears doubtful that any cloud can be surely seen to project unless its b is at least $0''.3$. One hence has by (12) for a barely observable projection on the limb:

$$\beta' = 2310/\delta. \tag{13}$$

Since the maximum useful value of δ is about $60''$ one sees by (13) that no cloud can be observed in profile unless its height is at least 40 miles. The application of (12) with b set equal to $0''.3$ to irregularities recorded on the limb or on the terminator when i was far from 90° shows β' to be 45 miles for Spangenberg's 1937 cloud, a result perhaps confirming the deduction from the occultation of η Geminorum. Wilson's and Ross' marks demand much greater values of β' and are hence more doubtful; Haas' require β' to be 200 miles or more, an inadmissible condition.

Clouds on the terminator not too far from dichotomy can be seen illuminated by very slanting solar rays while yet comparatively far from the terminator. Let the top T of a cloud be lit by a ray tangent to the terminator at S. Choose a point U such that the foreshortened view of $\overline{ST}$ obtained from the earth is $\overline{SU}$. It is true that:

$$\overline{SU} = \overline{ST} \cos \omega. \tag{14}$$

Now since $\overline{OS} = R$, $\overline{OT} = R + \beta'$, and $\angle OST = 90°$, it follows that in our ΔOST one has:

$$\overline{ST}^2 = \overline{OT}^2 - \overline{OS}^2 = 2R\beta' + \beta'^2. \tag{15}$$

By (14) and (15):

$$\overline{SU}^2 = (2R\beta' + \beta'^2) \cos^2 \omega; \tag{16}$$

but since β'^2 is small compared to $2R\beta'$, one can rewrite (16) with sufficient accuracy as:

$$\beta' = \frac{\overline{SU}^2}{2R \cos^2 \omega}. \tag{17}$$

In practice one will have to estimate the angular distance α from S to U in seconds. By analogy with (10):

$$\overline{SU} = \frac{\delta'\alpha}{\delta} = \frac{2R\alpha}{\delta}. \tag{18}$$

Equations (17) and (18) may be combined to give:

$$\beta' = \frac{7700\,\alpha^2}{\delta^2 \cos^2 \omega} \tag{19}$$

(for $2R = 7700$). Since β' is strongly dependent upon α and since the latter quantity has not to date been observed with any accuracy, (19) can only indicate the order of size of β'. We shall consequently not attempt to allow for the fact that the tip of a projection seen will not ordinarily be the top of a cloud lit by an exactly tangent ray. On October 13, 1940, Vaughn drew a hump near the middle of the terminator. Because of this position, we may with sufficient accuracy take ω to be $|\,90° - i\,| = 21°$ on that date. The value of δ was $17''.0$. Vaughn estimated the breadth of the hump to be between $0''.5$ and $1''.0$; we shall suppose α to be $0''.75$. These values substituted in (19) make β' to be 17 miles. This result is not implausible, and terminator-irregularities appear to be fully possible from a mathematical point of view.

The notorious condition of the problem of the period of rotation of Venus and of the inseparable problem of the orientation of the axis of rotation need not be reviewed here.[13] Attempts to determine the rotation from the motion of markings can give only the period of rotation of the atmosphere at the visible surface and not necessarily that of the solid surface beneath. Haas has proceeded as follows. He first ruled out the possibility of a short rotation-period because hours-long watches of the planet have disclosed to him no shift of detail and because he has often seen what he takes to be the same markings when making observations at greatly different hours on successive dates. Let L be the non-obtuse angle between two great circles upon the surface of Venus that intersect at K, the point on the visible surface directly below C, the one passing through the subsolar point Q and the other through some point readily identifiable on a series of drawings; and take L to be positive if the point lies west of the great circle through K and Q and negative if east, these directions being so selected that a direct rotation will shift marks from west to east. Haas measured L from drawings for five marks he had observed and for one Barcroft had observed.

Each measure determined a point in L and in time, measured in days; the slope of the Least Squares Line among such points was clearly the most probable daily angular motion A of the mark in L. Haas computed A to average $+0°.235$ for his marks and to be $+0°.371$ for Barcroft's mark. Let us now imagine ourselves at an infinitely great distance from Venus and near the plane of its orbit. Denote by r the period of revolution and by p that of rotation, both measured in days. The great circle through K and Q moves in a negative direction (recalling the convention about L) as Venus revolves around the sun, and at our station its daily angular motion will be almost constant and equal to $-360°/r = -1°.602$. For a direct rotation A will exceed the negative daily angular *rotational* shift by this amount so that:

$$A - 1°.602 = -360°/p \tag{20}$$

or:

$$p = \frac{360°}{1°.602 - A}. \tag{21}$$

With retrograde rotation the right side of (20) will have a positive sign, and (21) will become:

$$p = \frac{360°}{A - 1°.602}. \tag{22}$$

Direct rotation necessitates that $A < 1°.602$; retrograde rotation, that $A > 1°.602$. One will hence always know which one of (21) and (22) to use. These equations are not valid if the poles of rotation lie far from the cusps since then a significant portion of the rotational shift will not be effective in causing L to change. Equation (21) gives a period of 263 days for Haas' A and of 292 days for Barcroft's. Haas employed a method based on Student's distribution to set five per cent. fiducial limits to his own A;[14] the corresponding limiting values of his p are 223 days and 322 days.

By measures of a mark shown on his 1940 photographs in red Wilson obtained a retrograde rotation in 827 days, but he considers his results show only a very slow rotation.[2] Vaughn favours a rotation in about 24 hours, largely because a rapid rotation is needed to produce the belts he draws; he once observed a shift of detail compatible with such a period.

We inquire next about the value of ϵ, the angle between the plane of the orbit of Venus and the plane of its equator. The

drawings of Haas favour a near-coincidence of the two planes, for at all values of the heliocentric longitude H of the planet they reveal no progressive north or south motion of even the most stable markings. The fact that the two cusp-caps usually appear to be about the same size may argue for the same result. A stronger argument for a position of the poles near the cusps is the fact that the 1927 photographs by Ross and the 1940 ones by Wilson, which were taken at values of H *about 90° apart*, both show their dark bands to be perpendicular to the terminator. It appears unlikely to us that ϵ exceeds 15°, but more evidence is needed.

Notwithstanding the small value of ϵ to which we have been led, the fact that Coblentz and Lampland found the south cusp-cap much warmer than the other suggests the possibility of Venusian seasons.[7] From 1936 on our group, and especially Haas, has attempted to detect seasonal effects by observing which cusp-cap is the brighter, which (north or south) half of the limb-region is the brighter, and which (north or south) hemisphere contains the more and the darker shadings. It has been found that any seasons affecting the things watched are at best poorly expressed, but perhaps the south hemisphere is superior to the north as regards shadings when H is near 200°. The south hemisphere appears to be dominant over the north in all three matters in the long run. The markings here studied are at times subject to rapid and apparently irregular changes, the shadings less so than the cusp-caps or the limb-halves. Haas has found the shadings to favour one hemisphere in preference to the other for periods of as long as nine months.

Haas has made 68 comparisons of the relative darkness of the shadings at the middle of the limb, at the middle of the terminator, and at the centre of the disc regarded as circular (the last point is seen only when $i < 90°$) over all useful values of i. He found that the shadings grow steadily darker from Q to the terminator and are perhaps especially pronounced within about 15° of the terminator. This result appears to show that a low altitude of the sun is the primary condition promoting the visibility of the shadings and that they should accordingly perhaps be regarded as shadow-effects. It is pertinent to mention here Ross' inference from microphotometric measures of his 1927 negatives that the visible surface is uniformly billowy.[1]

It is important to know what observational techniques improve the visibility of the detail. The observers disagree as to whether the planet is best studied during the twilight or in full daylight; their discordant results are probably partly due to the fact that daylight work becomes ever more advantageous when the aperture is increased. Haas has concluded from the use of different telescopes that an aperture above about eight inches is a positive disadvantage, and Vaughn thinks that diaphragms of two or three inches lead to improved views. Haas finds that a red filter improves the visibility of dark detail and increases contrasts while a blue filter perhaps improves the visibility of bright areas although it decreases general contrasts. The bright limb-region appears much broader to him in blue than in red. However, Vaughn reports that blue filters supply much better views than red ones.

The controversial faint illumination of the dark hemisphere[4] was once suspected by Barcroft when i equalled 104°. Johnson has seen (falsely, he thinks) this area to be darker and a less pure blue than the daylight sky with i near 160°. With an 18-inch telescope between January 12 and February 19, 1942, i at observations ranging from 138° to 167°, Haas always found the unilluminated hemisphere to be exactly like the sky.

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SPECTROGRAPHIC ORBITAL ELEMENTS AND RELATIVE LUMINOSITIES OF THE COMPONENTS OF H.D. 203858

By C. G. Patten and A. McKellar

Section I—The Orbital Elements

THE binary nature of the star *H.D.* 203858 was announced by Harper[1] in 1937. Its position is defined by the coordinates $\alpha(1900)\ 21^h19^m.7$, $\delta(1900) + 24°\ 54'$ and it is of visual magnitude 6.22. The spectral type is given in the *Henry Draper Catalogue* as A0 but a revised spectral classification A1s is suggested later in this paper.

The lines in the spectrum of *H.D.* 203858, especially those due to metallic atoms and ions, are unusually sharp for this type of star. The spectra of both components are, at suitable phases, clearly recorded on single-prism spectrograms of moderate dispersion.

The earlier observations of *H.D.* 203858 for radial-velocity measurement were made at this observatory in 1926, 1927, 1930 and 1937. Observations were resumed more intensively in 1940 and continued through the following year. The orbital elements as reported in the present publication have been computed on the basis of data obtained from a total of 29 plates. All of these observations were made with the single-prism spectrograph, which gives a dispersion at λ4340 of 30 Angstrom units per mm. The observational material is given in Table I, where the headings of the columns are self-explanatory. As well as the 29 spectrograms recorded in Table I, six other plates were taken upon which the lines were fairly diffuse. The phases of these six observations were such that, from present orbital data, blended lines were to be expected on the spectrograms.

On the plates showing both spectra, about seven lines were measured for each component from among Ca II, λ3933; Fe I, λλ4045, 4063, 4071; Sr II, λ4077; H, λ4101; Fe II, λ4233; H, λ4340; Mg II, λ4481; Fe II, Ti, II, λ4549. On plates showing sharply single lines, many more could have been measured.

The period of revolution was readily found; the early observa-

[1] *Pub. Dom. Ap. Obs.*, vol. 7, 1, 1937.

TABLE I. OBSERVATIONS OF *H.D.* 203858

No.	Date (U.T.)	Julian Day 2,400,000+	Phase		Primary					Secondary				
			from Final T_{T_0}	from Final T	Radial Velocity	Residual (O − C) Circular Solution	Residual (O − C) Elliptical Solution	Wt.	n	Radial Velocity	Residual (O − C) Circular Solution	Residual (O − C) Elliptical Solution	Wt.	n
		days	days	days	km./sec	km./sec	km./sec			km./sec.	km./sec.	km/sec		
1	1926, Oct. 12	24,800.762	4.238	5.056	−63.5	+0.9	−0.8	0.4	3	+37.4	+4.4	+6.4	0.3	3
2	1930, Aug. 8	6,196.906	4.175	4.994	−61.5	0.0	−1.8	0.4	2	+31.4	+2.1	+4.0	0.3	2
3	1937, Aug. 3	8,748.919	6.896	0.768	−19.7	+3.2	+3.0	1.2	18	−19.7	−3.4	−3.1	0.9	18
4	Sept. 7	8,783.824	0.124	0.942	−15.2	−4.1	−5.5	0.8	23	−15.2	+14.0	+16.0	0.6	23
5	1940, Sept. 25	9.897.733	2.624	3.443	+27.1	−3.0	−2.2	0.4	3	−69.1	+7.0	+5.8	0.3	3
6	" 30	9,902.696	0.641	1.460	+14.7	−5.0	−6.0	0.8	4	−72.6	−8.5	−6.6	0.6	4
7	Oct. 1	9,903.772	1.717	2.536	+49.5	−2.5	−2.1	1.2	5	−107.2	−6.2	−5.6	0.9	5
8	" 2	9,904.665	2.610	3.429	+29.1	−1.8	−0.6	1.2	11	−68.7	+8.6	+7.6	0.9	11
9	" 2	9,904.812	2.757	3.576	+21.3	−2.2	−1.0	1.2	10	−73.3	−5.2	−6.3	0.9	10
10	" 9	9,911.738	2.737	3.555	+26.0	+1.1	+2.0	1.2	7	−65.9	+4.0	+3.0	0.9	7
11	" 16	9,918.640	2.693	3.511	+22.6	−4.1	−3.5	1.2	7	−67.6	+5.0	+4.0	0.9	7
12	" 22	9,924.741	1.847	2.666	+54.1	+2.3	+2.7	0.8	6	−100.8	−0.1	+0.6	0.6	6
13	" 25	9,927.658	4.764	5.583	−83.7	+1.2	+1.2	1.2	8	+55.1	0.0	+0.3	0.9	8
14	Nov. 1	9,934.630	4.790	5.608	−89.8	−4.0	−4.0	1.2	6	+59.3	+3.3	+3.3	0.9	6
15	" 3	9,936.704	6.864	0.736	−18.2	+6.5	+6.0	1.2	9	−18.2	−4.1	−3.1	0.9	9
16	" 21	9,954.742	4.063	4.881	−55.8	−0.2	−2.0	0.4	5	+17.0	−4.1	−3.5	0.3	5
17	1941, May 8	30,122.985	5.595	6.413	−89.2	−2.6	−0.8	1.2	6	+68.1	+11.0	+9.1	0.9	5
18	" 29	0,143.967	5.738	6.556	−84.7	−1.8	0.0	1.2	7	+56.6	+3.9	+1.6	0.9	6
19	June 1	0,146.952	1.777	2.595	+49.1	−2.6	−2.0	1.2	7	−103.0	−2.2	−1.8	0.9	7
20	July 17	0,192.967	6.114	6.932	−73.6	−8.0	−6.0	0.4	4	+35.0	−1.2	−2.3	0.3	4
21	" 29	0,204.796	4.050	4.869	−50.1	+3.8	+2.0	0.4	5	+37.9	+17.0	+19.0	0.3	5
22	" 30	0,205.950	5.204	6.023	−97.3	−6.0	−5.0	0.8	6	+65.8	+3.8	+2.2	0.6	5
23	Aug. 1	0,207.981	0.289	1.107	−19.2	−18.0	−19.2	0.4	7	−19.2	+21.0	+22.2	0.3	7
24	" 5	0,211.949	4.257	5.075	−69.2	−3.2	−4.2	0.8	7	+27.2	−6.4	−5.0	0.6	6
25	" 6	0,212.975	5.283	6.101	−93.2	−2.2	−0.6	1.2	7	+58.9	−3.0	−4.3	0.9	7
26	" 9	0,215.707	1.069	1.887	+37.3	−2.0	−3.0	1.2	8	−88.6	−2.5	−2.0	0.9	7
27	" 9	0,215.771	1.133	1.951	+39.6	−2.3	−3.2	1.2	7	−84.1	+4.0	+5.0	0.9	6
28	" 9	0,215.983	1.345	2.163	+46.8	−0.5	−1.2	1.2	6	−92.6	+3.2	+3.5	0.9	6
29	" 10	0,216.791	2.153	2.971	+53.2	+6.9	+6.5	1.2	8	−88.3	+7.8	+8.0	0.9	8

tions enabled it to be determined with considerable precision, since an interval of 780 cycles separated the first and last observations. The value finally adopted was 6.9463 days. It is estimated that this is accurate to 0.0001 days. In carrying out the least-squares solutions the period was considered fixed at the above figure.

An examination of the form of the radial-velocity curves of the two component stars indicated that the orbits were very closely circular. It was therefore decided to perform a least-squares solution to obtain the elements of circular orbits.

For the purpose of obtaining preliminary elements and making less tedious the carrying out of the solution, the 29 observations were assembled into 10 normal places. The mean phases, velocities, residuals and the weights of these normals are given in Table II. The preliminary elements obtained are shown in Table III. The differential equation of condition used to obtain by least squares the corrections to the preliminary elements was:

$$\delta V = \delta V_0 + \sin\theta.\delta K_1 - \sin\theta.\delta K_2 - (K_1\cos\theta - K_2\cos\theta)\,\delta\theta_0.$$

This was obtained from the equations for radial velocity,

$$V_p = V_0 + K_1\sin(\theta - \theta_0)$$
$$V_s = V_0 - K_2\sin(\theta - \theta_0).$$

Here V_0, K_1 and K_2 have their usual meaning, the angle θ_0 was used to define the time T_{v_0} at which the radial velocity of the primary star, going from negative to more positive values, is equal to the systemic velocity, V_0, and $\theta = n(t - T_{v_0})$. From the twenty observation equations derived from the normals of Table II and the preliminary elements in Table III, the following normal equations were obtained:

$$\begin{aligned} 47.6000x + 3.2734y - 2.4552z - 0.0135u + 0.1900 &= 0 \\ +16.6340 \quad 0.0000 + 0.0498 + 17.8138 &= 0 \\ +12.4753 + 0.0424 + 7.0280 &= 0 \\ +10.8837 + 50.2369 &= 0 \end{aligned}$$

The solution of these normals gave the following corrections to the preliminary elements,

$$\delta V_0 = x = +0.04 \text{ km./sec.}$$
$$\delta K_1 = y = -1.06 \quad \text{“}$$
$$\delta K_2 = z = -0.54 \quad \text{“}$$

TABLE II. NORMAL PLACES

	Primary							Secondary						
	Mean Phases		Mean Radial Velocity	Residuals			Wt.	Mean Phases		Mean Radial Velocity	Residuals			Wt.
	from Final T_{V_0}	from Final T		Prelim.	from Circular Solution	from Elliptical Solution		from Final T_{V_0}	from Final T		Prelim.	from Circular Solution	from Elliptical Solution	
	days	days	km./sec.	km./sec.	km./sec.	km./sec.		days	days	km./sec.	km./sec.	km./sec.	km./sec.	
1	0.016	0.834	−18.1	+3.7	+0.4	−0.3	3.6	0.016	0.834	−18.1	−1.2	+2.6	+3.2	2.7
2	0.641	1.459	+14.7	−2.7	−5.0	−6.2	0.8	0.641	1.459	−72.6	−11.4	−8.5	−7.2	0.6
3	1.182	2.000	+41.2	−1.2	−2.0	−2.3	3.6	1.182	2.000	−88.4	+1.1	+2.5	+2.8	2.7
4	1.876	2.694	+51.2	−1.6	−0.2	+0.8	4.4	1.876	2.694	−99.7	+1.5	+0.6	−0.6	3.3
5	2.693	3.511	+24.9	−5.1	−1.9	−1.6	5.2	2.693	3.511	−68.9	+6.6	+3.4	+2.9	3.9
6	4.173	4.991	−61.6	−1.9	+0.2	−1.6	2.4	4.173	4.991	+29.7	+3.8	+1.0	+2.9	1.8
7	4.777	5.595	−86.8	−1.6	−1.3	−1.4	2.4	4.777	5.595	+57.2	+2.4	+1.4	+1.5	1.8
8	5.251	6.069	−94.8	−2.8	−3.9	−2.6	2.0	5.251	6.069	+61.7	−0.8	−0.2	−1.8	1.5
9	5.667	6.485	−87.0	+0.2	−2.1	−0.1	2.4	5.667	6.485	+62.4	+5.4	+7.3	+5.0	1.8
10	6.114	6.932	−76.3	−4.8	−8.0	−6.4	0.4	6.114	6.932	+35.0	−4.3	−1.2	−3.1	0.3

TABLE III

ORBITAL ELEMENTS OF *H.D.* 203858

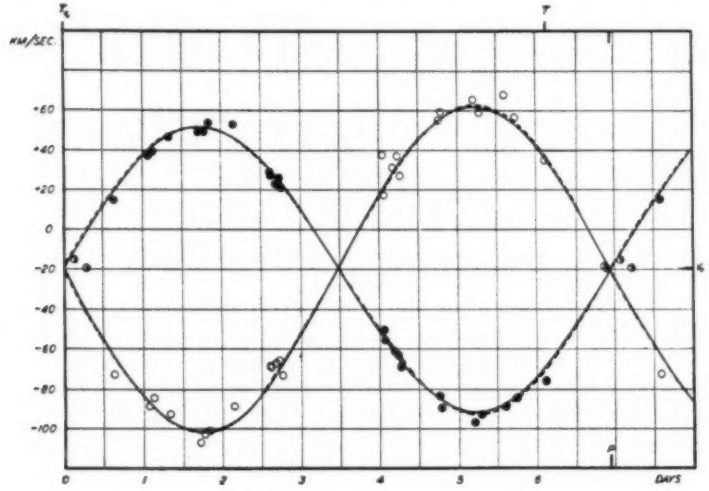
Element	Preliminary Value	Value from Circular Solution	Value from Elliptical Solution
P	6.9463 days	6.9463±0.0001 days	6.9463±0.0001 days
T			J.D. 2,430,005.431±0.432
T_{v_0}	J.D. 2,430,006.300	J.D. 2,430,006.249±0.011	
ω_1			227°± 22°
ω_2			47°± 22°
e			0.022± 0.027
K_1	72.5 km./sec.	71.44 ± 0.78 km./sec.	71.70 ± 0.76 km./sec.
K_2	82.0 "	81.46 ± 0.90 "	81.75 ± 0.88 "
V_0	−19.5 "	−19.46 ± 0.46 "	−19.44 ± 0.45 "
$a_1 \sin i$		6,820,000 km.	
$a_2 \sin i$		7,780,000 "	
$m_1 \sin^3 i$		1.37⊙	
$m_2 \sin^3 i$		1.20⊙	

$$\delta\theta_0 = \frac{u}{100} = -0.0461 \text{ radians} = -2.64°.$$

This solution was found to converge very satisfactorily, and by it the sum of the squares of the residuals, Σpvv, was reduced by 49 per cent from 246 to 125 for the primary star and by 37 per cent from 358 to 227 for the secondary. The probable errors of the orbital elements and also of the radial-velocity determinations were computed in the usual manner. It was found that the probable error of a normal place of unit weight, r_0, was ±3.2 km./sec. For the primary, a normal place of average weight had a probable error of ±1.5 km./sec. while for the secondary the corresponding figure is ±2.3 km./sec. The probable error of the radial-velocity determination from a single plate of average weight is, for the primary star, ±2.8 km./sec., and for the secondary, ±4.5 km./sec. The final circular orbital elements and their probable errors are shown in Table III. The radial-velocity curves, where the individual radial velocities from each plate are plotted and the full-line curves represent those calculated from the circular elements, are shown in the accompanying figure.

While the circular orbital elements represent the observations

very well, it was considered that this star presented a case for which the orbits could profitably be treated using a least-squares method recently suggested by Sterne.[2] Sterne's method, which is applicable to orbits of very low eccentricity, avoids the difficulties encountered in dealing with the almost indeterminate elements T and ω and the calculation of their true probable errors. The solution requires circular elements as preliminary ones and, as well as allowing the derivation of corrections to the elements V_0, K_1, K_2, and T, enables the determination of e and ω by yielding values of the functions



RADIAL-VELOCITY CURVES OF H.D. 203858

$e \sin \omega$ and $e \cos \omega$. In the solution, instead of T, the time of periastron passage, the related time $T_0 = T - \frac{\omega}{n}$ occurs. This is the time at which the mean longitude is zero, n being the mean daily angular motion. From Sterne's work, the equation of condition for carrying out a solution for the case of a double-line binary is readily found to be:

[2] *Pr. Ac. Sc., Wash.*, **27**, 175, 1941.

$$\delta V = \delta V_0 + \cos L_1 \,.\, \delta K_1 + \cos L_2 \,.\, \delta K_2 +$$
$$(K_1 \,.\, \cos 2L_1 - K_2 \,.\, \cos 2L_2)\, e \cos \omega +$$
$$(K_1 \,.\, \sin 2L_1 - K_2 \,.\, \sin 2L_2)\, e \sin \omega +$$
$$(K_1 \,.\, \sin L_1 + K_2 \,.\, \sin L_2)\, n\delta T_0$$

where L = mean longitude $= v + \omega$ and the other symbols have their usual meaning.

For *H.D.* 203858, the preliminary circular elements adopted were the final elements obtained by the least-squares solution as described above. The value of T_0 was taken as

$$T_{r_0} + \frac{6.9463}{4} = \text{J.D. } 2{,}430{,}007.986.$$

The same normal places used in the previous solution were again employed. The normal equations were found to be,

$$\begin{array}{rrrrrrr}
47.6000x + & 3.2767y - & 2.4575z + & 0.6233u + & 0.0722v + & 0.0033w + & 0.0870 = 0 \\
+16.6138 & 0.0000 + & 0.3956 + & 1.5950 + & 0.2474 - & 1.3967 = 0 \\
& +12.4605 + & 0.3385 + & 1.3639 + & 0.2114 - & 1.0277 = 0 \\
& & +13.6430 - & 0.1831 + & 2.2213 + & 18.3953 = 0 \\
& & & +13.7761 + & 2.7433 + & 19.3338 = 0 \\
& & & & +10.6716 + & 0.6493 = 0
\end{array}$$

The solutions of these equations gave,

$$\begin{array}{llll}
x = \delta V_0 = +0.02 \text{ km./sec.} & & u = 100.e \cos \omega = & -1.4917 \\
y = \delta K_1 = +0.26 \quad " & & v = 100.e \sin \omega = & -1.6111 \\
z = \delta K_2 = +0.29 \quad " & & w = 100.n.\delta T_0 = & +0.6520
\end{array}$$

from which $e = 0.022$

$$\omega_1 = 227° \text{ and } \omega_2 = 47°,$$
$$\text{and } \delta T_0 = +0.007 \text{ days.}$$

The final elements for these elliptical orbits, with their probable errors, are given in the last column of Table III. This solution, which was found to converge well, further reduced the sum of the squares of the residuals by 17 per cent (the primary by 15 per cent and the secondary by 18 per cent). For comparison with the corresponding figures from the circular solution, it was found that the probable error of a normal place of unit weight, r_0, was ± 3.1 km./sec., while the probable errors of normals of average weight were, for the primary ± 1.4 km./sec. and for the secondary, ± 2.1

km./sec. For an individual determination of average weight, the probable error in radial velocity was found to be ±2.8 km./sec. for the primary and ±4.4. km./sec. for the secondary. The radial-velocity curves from the elliptical elements are very similar to those from the circular elements and are shown in the figure by broken lines.

It might be noted in passing that Sterne's method is a very convenient one to use from the computer's standpoint. The simplification in using circular preliminary elements and the ease of setting up the observation equations are noteworthy.

The question arises as to which set of orbital elements, the circular or elliptical, are best for *H.D.* 203858. From the point of view that the set of elements giving the smallest Σpvv is best, the elliptical elements would be judged superior. However, when it is noted that the eccentricity is 0.022 ± 0.027, it is clear that within the probable errors of determination, the orbits are essentially circular. The lower sum of the squares of the residuals given by the elliptical elements could well be ascribed to the two extra variables available in the elliptical description of the orbits. Hence, for *H.D.* 203858, the writers conclude that circular orbital elements are adequate to describe the observations. In cases where it is of primary importance to determine whether or not an orbit has a small real eccentricity, it is suggested that the most reliable results could be obtained by employing many more observations than used here, and treating them by Sterne's least-squares method.

Section II—Relative Luminosities; Stellar and Orbital Dimensions

H.D. 203858, in the spectrum of which as already noted the lines of both stars show very clearly, is a suitable object to which to apply the methods of R. M. Petrie[3] for the determination of the magnitude difference, Δm, between the component stars. The value of such a determination in the present case lies in the fact that it makes possible a calculation of the absolute dimensions of the two stars and their orbits.

For the determination of Δm, eight plates were chosen for study, namely observations 3, 14, 15, 17, 18, 26, 27 and 28 in Table I.

[3] *Pub. Dom. Ap. Obs.*, **7**, 205, 1939.

Two of these show the most sharply single lines, three show widely separate double lines with the primary star approaching and three show widely double lines with the primary star receding. All these plates had been calibrated spectrophotometrically, using a rotating sector and auxiliary spectrograph. The two spectral lines judged best for the present purposes were λ3933 of Ca II and λ4481 of Mg II. Tracings of these lines were made with the microphotometer and from these, intensity profiles were derived. Expressions for obtaining l, the relative luminosity of the secondary star to that of the primary, from measurements of both the central and total intensities of the single and double lines, are given in detail in reference 3 so will not be repeated here. The results of the evaluation of l by these expressions are shown in Table IV, where it is seen that the final mean value is $l = 0.75 \pm 0.05$. This reduces, in units of stellar magnitudes, to $\Delta m = 0^m.1 \pm 0.07$. In arriving at this mean, the fifth and sixth determinations in the final column, for which the λ4481 components were completely separated, hence providing the best possible condition for obtaining l, were given double the weight of each of the other determinations. It will be

TABLE IV

MEASUREMENTS OF THE RELATIVE LUMINOSITY OF THE PRIMARY AND SECONDARY STARS

Observation No.	l			
	From central Intensities of *K* line of CaII	From total Intensities of *K* line of CaII	From central Intensities of λ4481 of Mg II	From total Intensities of λ4481 of Mg II
14	0.64	1.14	0.83	1.00
17	0.65	1.07	0.66	0.68
18	0.60	0.91	0.66	0.54
26	0.76	0.74	0.61	0.56
27	0.93	0.87	0.71	0.61
28	0.68	1.07	0.73	0.58
Mean....	0.71 ± 0.03	0.97 ± 0.04	0.70 ± 0.02	0.64 ± 0.04

Mean value of $l = 0.75 \pm 0.05$
Hence, value of $\Delta m = 0^m.31 \pm 0.07$.

noted that the second column shows values of l definitely higher than those of the other columns. This probably means that the K line of Ca II has a somewhat greater total intensity in the secondary spectrum relative to λ4481 (and possibly to the other spectral lines present) than it has in the spectrum of the primary star. Hence the secondary star is probably of slightly later spectral type than the primary.

Having determined Δm as above, it is necessary to obtain a value of the absolute magnitude of *H.D.* 203858 in order to determine the actual dimensions. Unfortunately there does not appear to be available a trigonometric parallax for this system. However, using the as yet unpublished spectroscopic criteria of Harper for the estimation of the absolute magnitudes of A-type stars, the absolute magnitude of *H.D.* 203858 was judged to be +0.3. The criteria pointing to this luminosity, somewhat above the average for A-type stars, were the extreme sharpness of the spectral lines and the appearance, with considerable strength, of lines of Sr II, Si II and Fe II. It is suggested that the spectral type of this star might well be revised from A0 to A1s.

Taking the effective temperatures of the component stars of *H.D.* 203858 as 10,700°K, following Kuiper,[4], the radii of the two stars were immediately calculable. Then using Kuiper's data[4] on the mass-luminosity relation, the value of the inclination of the

TABLE V

ABSOLUTE STELLAR AND ORBITAL DIMENSIONS FOR THE SYSTEM *H.D.* 203858

	Primary star	Secondary star
Spectral Type	A1s	A1s
Absolute Visual Magnitude	+0.91	+1.21
Parallax (Spectroscopic)	0″.0065	0″.0065
Effective Temperature	10,700°K	10,700°K
Inclination of Orbital Plane	49°	49°
Stellar Radius	2.20⊙	1.91⊙
Stellar Mass	3.13⊙	2.90⊙
Mean Stellar Density	0.30⊙	0.41⊙
Radius of Orbit	9,040,000 km.	10,300,000 km.

[4] *Ap. J.*, **88**, 429, 1938.

orbital plane was found to be 49°, allowing the computation of the stellar masses and mean densities and the radii of the stars' orbits. The values of these quantities, which are assembled in Table V, are seen to be quite reasonable for A-type stars of somewhat above average luminosity.

Dominion Astrophysical Observatory,
Victoria, B.C.,
September, 1942.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Meteors on the Moon

In his thorough discussion of the question, "Does anything ever happen on the moon?" in this JOURNAL last year Mr. W. H. Haas referred to the possibility of meteors on our satellite, but no clear evidence that such had ever been seen was available. The matter was referred to again in Notes and Queries in our March issue. Further information on this interesting—almost romantic—subject comes in a letter from the Harvard Observatory which follows.

Occasionally one hears discussions on the possibility of observing meteors on the moon, but as yet I have seen practically nothing on specific observational results, negative or otherwise. Hence I was interested in your quoting Mr. E. K. White's observations during the recent lunar eclipse, in the March JOURNAL.

When Dr. Opik (of Esthonia) was in Cambridge in 1934 we discussed this problem of observing "lunar" meteors and I planned to observe the nearly-new moon regularly, an ambition that multifarious circumstances did not permit me to carry very far. We decided that the Harvard 15-inch would be about the smallest suitable instrument for the purpose, and as it was also our largest visual telescope, decided to use it, adjusting the field so as to have a maximum area of the dark of the moon in the field and none of the illuminated crescent. As any pessimist might expect, most near-new moon evenings were not suited to observing, and I have records of only a total of four observing hours in four nights that were satisfactory for the purpose (2 in 1934, and 2 in 1936). I observed nothing that could unmistakably be called a meteor. A few times I thought I saw faint "sparks" on the moon that may or may not have been real. More probably they were merely dust in the eyepiece suddenly illuminated by stray traffic lights which all too frequently disturb observing in Cambridge. Nothing more came of my observing. Cambridge with its city lights and unsteady atmosphere did not seem well suited to the programme. I am, however, interested to hear more about other people's observational attempts with the problem.

DORRIT HOFFLEIT.

Predictions which were not Fulfilled

In the course of an address before the American Association of Physics Teachers, entitled "The New Spirit in American Physics," Prof. Gordon Ferrie Hull, of Dartmouth College, in New Hampshire, relates some interesting incidents in the history of Physics. Professor Hull was born at Garnet, a village not far from Hamilton, Ont., and

graduated B.A. from the University of Toronto in 1892—two years later than the present writer. He has been associated with Dartmouth since 1899. The address is published in the *American Journal of Physics* for February 1943, and a small portion is given herewith.

In the middle of the nineteenth century, the law of the conservation of energy was established. Later Maxwell, a giant among men, made light an electrical phenomenon and postulated the existence and properties of electric waves. Only a dozen years before the twentieth century these waves and the photoelectric effect were discovered by Hertz. The physicists of the world viewed the great structure which had been reared and pronounced it nearly complete. Perhaps more than one physicist pictured the condition of physics thus: "it can now, with assurance, be stated that all the great discoveries in physics have been made—from now on progress will lie in the seventh place of decimals." This statement has been attributed to various authors. I only know that in the spring of 1895 I received a circular outlining the programme in physics in an important American university and containing that statement. It had been written by, or at least sponsored by, one of the foremost of American physicists.

Thus in the spring of 1895, we were told that there were no new realms to be opened up, no glorious adventures in physics. A man would have to be a mathematical giant or a genius in experimental skill to achieve recognition. Then there occurred a series of earthquake shocks—shocks that shook the world of physics, that shook the entire world. On December 28, 1895, Röntgen announced the discovery of a strange radiation to which he gave the name x-rays. This triggered off the discovery by Becquerel of uranium rays in 1896, and this in turn led Madame and Pierre Curie to a glorious triumph in the discovery of polonium and radium in 1898. In the preceding year J. J. Thomson made clear the nature of cathode rays by the final identification of the electron. (Faraday nearly discovered it 60 years earlier; Johnstone Stoney in 1874 gave it the name it now has and made an approximate computation of its charge. Henceforth it was out in the open and could be produced at will.) No difficult mathematical operations, no measurements involving the seventh place of demicals were necessary in these great discoveries. But when we come to the next great advance—the proposal by Planck in 1900 that radiant energy was not continuous but was tied together in bundles each proportional to the frequency—we do meet mathematical operations of considerable difficulty and obscure concepts lacking apparent reality. Moreover, Planck was under compulsion to fit his theory to the laws of blackbody radiation, empirical laws arrived at through a long series of experiments of the highest precision.

Along another line it should be noted that, in 1895, it was discovered that an inert gas—argon—constituted nearly 1 per cent. of our atmosphere. (The fact that there was a 1-per cent. residue of some sort was discovered by Cavendish

100 years earlier.) In 1898 the other inert gases in the atmosphere—neon, krypton, xenon—were discovered. In 1895 helium was isolated from uraninite, a fact of very great importance when, a few years later, attempts were made to analyse the phenomena of radioactivity.

No other period of five years can rank with these years in their revolutionary upsurge of discoveries in physics. They set the world on fire.

C. A. C.

Sources of Two Quotations

It may be of interest to state that Simon Newcomb's simple but satisfying testimony to the greatness of Copernicus, quoted in our last number (page 167), was given in an address by Newcomb on "The Problems of Astronomy" delivered at the dedication of the Flower Observatory of the University of Pennsylvania, May 12, 1897. It was printed in *Science* of May 21, 1897; and later in the Report of the Smithsonian Institution for 1896.

. . . . .

Recently there was brought to the writer's attention a travesty on the first stanza of Jane Taylor's immortal poem:

Twinkle, twinkle, little star!
How I wonder what you are!
Far above the world so high
Like a diamond in the sky.

It seemed to bring back impressions received half a century ago but the precise circumstances could not be recalled. Perhaps some reader can supply the name of the perpetrator of this:

Scintillate, scintillate, globule vivific!
Fain would I know thy nature specific,
Suspended in ether far and capacious,
Somewhat like a gem carbonacious.

C. A. C.

MEETINGS OF THE SOCIETY

AT MONTREAL

February 25, 1943.—Continuing the series of popular lectures, Mr. E. Russell Paterson addressed the Montreal Centre on "The Planets."

Speaking first of the characteristics common to all planets, Mr. Paterson emphasized the following points: (1) Planets shine steadily without twinkling. (2) A planet shows as a disk through a telescope whereas all stars are just pin-points. With the unaided eye, Mr. Paterson explained, one can see objects occupying three to four minutes of arc, while with a powerful telescope one can see down to 1/100 of a second of arc, which is the equivalent of a ten-cent piece held fifteen miles away. (3) The planets move against the background of the pattern of stars. (4) They travel in elliptical orbits which are nearly circular. (5) They shine by the reflected light of the sun. (6) The surface conditions of a planet depend largely on its distance from the sun. (7) The planets account for only one-seventh of one per cent. of the total mass of the solar system. Each member of the audience had been given copy of a chart, showing the mass, density, diameter, velocity of escape, etc., of the sun, moon and planets, to which Mr. Paterson made frequent reference when elaborating on the above points.

Mr. Paterson then spoke of the surface conditions of each planet in turn. The planet Mercury, he said, is too small to hold any appreciable atmosphere, and he gave a concise explanation of the term "velocity of escape"—the speed necessary to escape from the gravitational pull of the planet. Venus, through a telescope, shows the same phases as the moon, but dense layers of clouds make it impossible to find out anything about surface conditions. Mars, on the other hand, is the clearest and easiest planet to observe and in forty continuous nights of observation one can see the whole surface. An interesting fact about Phobos, one of the moons of Mars, is that it revolves on an orbit dangerously close to the planet. According to "Roche's Limit," the distance of a satellite must be at least one and a half times the radius of the planet or the gravitational pull will draw it in until it disintegrates to form a ring like those of Saturn. Of particular interest also was the story of the search for the undiscovered planet that was throwing Uranus "off schedule," and whose existence was first proved mathematically.

As astronomers differ on the actual surface conditions of the planets, Mr. Paterson had taken as his authority H. Spencer Jones, the Astronomer Royal, whose book "Worlds Without End" he recommended very highly to the new members.

ISABEL K. WILLIAMSON, *Recording Secretary.*

March 11, 1943.—Dean H. F. Hall's lecture on "The Nature of the Stars" was the fifth in the series for new members.

If we watch the sky for a period of fifteen minutes, said Mr. Hall, we can see the orderly movement of the stars as though fixed in position on a great wheel. Actually, the stars move in relation to each other, but their distances from the earth are so great that no change in relative positions is noticeable in our lifetime. Neither does any change in our position make any noticeable shift in the stars. The angle which a star moves can be measured, however, by fine instruments and the apparent movement of a star over a period of a year is called its "parallax." Knowing the parallax of a star gives us a way of measuring its distance from our solar system. A star 3.26 light-years from us would have a parallax of one second of arc, and for this distance of 3.26 light-years the term "parsec" is used as a convenient unit of length. No star moves through a parallax as great as one second of arc, the nearest star, Proxima Centauri, being 4.25 light-years away.

Mr. Hall then explained how the stars are classified according to their brightness as seen from the earth, or their "apparent magnitude," as it is called. Stars of the first magnitude are 2.512 times brighter than stars of the second magnitude, $(2.512)^2$ times brighter than third magnitude stars, and so on. In classifying stars according to their "absolute magnitude," or true luminosities, absolute magnitude equals apparent magnitude at ten parsecs. The absolute magnitude of a star, therefore, is greater or less than its apparent magnitude depending on its distance from the earth.

The stars also differ in colour and the greatest instrument for examining the nature of the stars is the spectroscope. Mr. Hall explained how the lines in a spectrum reveal the presence of different elements, and he gave the categories into which stars are placed according to their chemical composition. The hottest and bluest stars (Type O) have temperatures of over 30,000° C. The spectrum of this type shows ionized helium but the lines of the metallic elements are absent. The white (Types B, A & F), yellow (G), orange (K) and red (M) stars range in temperature from 20,000° for Type B to 3,000° for Type M. Weak metal lines show up in the spectrum of Type A stars and become more prominent in the lower groups. Type G stars, to which class our sun belongs, show prominent lines for iron, nickel and calcium.

Mr. Hall also spoke of the Russell diagram, developed by Henry Norris Russell, on which samples of stars in our neighbourhood are plotted according to type and magnitude, with the surprising result that the stars distribute themselves across the chart in a natural sequence.

ISABEL K. WILLIAMSON, *Recording Secretary.*

March 25, 1943.—"The Use of the OBSERVER'S HANDBOOK" was the subject of a very helpful talk given by Mr. F. DeKinder to the new members of the Montreal Centre.

The HANDBOOK is really very easy to read and use, Mr. DeKinder assured

his audience. At first glance it is apt to appear incomprehensible but we should experience no great difficulty if we become thoroughly familiar with the symbols and abbreviations on page 4. A knowledge of these symbols is essential for reading the section "Astronomical Phenomena Month by Month." Mr. DeKinder also stressed the importance of learning the Greek alphabet, which is used on all sky charts and atlases to identify the individual stars in the various constellations. He then went through the HANDBOOK, a section at a time, emphasizing certain points and elaborating on others with blackboard diagrams. With reference to the table on page 7, he explained, the sun crosses the meridian at mean-time noon only four times during the year. This is due to the fact that the earth revolves about the sun on an elliptical orbit, travelling fastest when nearest the sun and covering equal areas of zone in equal periods of time.

Another piece of advice Mr. DeKinder gave his listeners was to read carefully the section on "The Planets for 1943." The planets afford most interesting observation for the amateur and it is well to know in advance the most favourable time for observing each planet. For instance, an opportunity will be given to locate Venus in broad daylight when, soon after moonrise on the morning of July 6, the planet is occulted by the moon.

Mr. DeKinder's talk, coming as the sixth in the series of ten popular lectures, enabled the members to make some practical application of the information accumulated from the preceding lectures.

ISABEL K. WILLIAMSON, *Recording Secretary.*

March 26, 1943. Joint Meeting.—Upon the invitation of the McGill University Chapter of Sigma Xi the members of the Montreal Centre of the Royal Astronomical Society of Canada enjoyed the privilege of attending the meeting held in the Macdonald Physics Building, McGill University, to commemorate the four-hundredth anniversary of the death of Copernicus. Dr. D. A. Keys was in the chair. The speaker of the evening was Dr. A. Vibert Douglas, newly elected President of the Royal Astronomical Society, and among the special guests were Prof. George Vibert Douglas of Dalhousie University, Halifax, Dr. Tadeusz Brzezinski, the Polish Consul, and Dr .W. W. Francis, librarian of the Sir William Osler Library.

In introducing her subject Dr. Douglas spoke briefly of the years covered by the life-span of Copernicus (1473-1543) which were times of great intolerance in scientific and religious thought but also times of great venture and enterprise. Nicholas Koppernigk, or Copernicus, (as was the custom in those days, he Latinized his name when publishing his works) was born in the town of Torun in Poland. The education of Copernicus covered a wide field. From a school in Torun he went to the University of Krakow where he studied for five years. At this time, it is to be remembered, the Aristotelian and Ptolemaic theories of the universe were believed and taught. At the age of twenty-three he went to Bologna and studied at the School of Law for four years. He then went to Rome where he taught private pupils in mathematics. He studied medicine in

Padua and received his doctorate in canon law in Ferrara in 1503. In his early years he was also a painter of some repute but he gave up this pastime as being too frivolous when he became a canon. He was intensely interested in the government and welfare of his country and rendered valuable service on diplomatic missions. When war broke out between Poland and Russia he proved to be a man with outstanding qualities of leadership. During these busy years he found time to lay the foundation for his planetary theory. When peace came to his country he had more time at his disposal and in the years 1523-32 he revised the manuscript of his great book, but owing to the growing intolerance of the times he made no attempt to publish it lest the opposition it would receive might interfere with his further observations. When nearly seventy he finally decided to have it published and on May 24, 1543, just a few hours before he died, the book was placed in his hands.

"De Revolutionibus Orbium Celestium" advanced the theory that "in the midst of all is the sun." It explained the diurnal motion of the earth, its annual revolution round the sun and the cycle of the seasons. It also described the movements of the moon and the two inner and three outer planets and affirmed the extreme distance of the stars. From its elaborate diagrams and tables it is obvious that Copernicus meant his book to be taken as a statement of physical fact. At that time, however, to read it meant to be threatened with torture and the stake. Early in the seventeenth century "De Revolutionibus" was placed on the "Index Librorum Prohibitorum" and was not actually removed until 1835.

William Gilbert, English physician and physicist, was an ardent advocate of the Copernican theory. The Italian philosopher, Giordano Bruno, placed his life in jeopardy by supporting the Copernican cosmology and went to the stake in Rome in 1600. The observations of Galileo placed the Copernican theory on a firm basis, but Galileo was prevented by intolerance and the binding together of religious and scientific views from openly supporting it. Kepler made the further contribution that the planets moved, not in circular, but in elliptical orbits, and Newton finally established the Copernican theory on a firm mathematical basis.

Copernicus thus had displaced the earth as the centre of the universe. The sun was later displaced when found to be only a star in our galaxy, and in turn our own galaxy was displaced as more powerful telescopes revealed other galaxies.

At this point in her address Dr. Douglas showed a number of slides. The first was from the brochure on "Nicholas Copernicus," the book by Stephen P. Mizwa, A.M., LL.D., recently published by the Kosciuszko Foundation in commemoration of the death of Copernicus. Of particular interest was a slide of the title page of the first edition of "De Revolutionibus." When showing the University of Krakow Dr. Douglas mentioned that for the first time in over five hundred years (1364-1939) the doors of this University were closed when, following the Nazi invasion of Poland, the entire faculty was assembled on

November 6, 1939, and taken to concentration camps. There were also several beautifully coloured old slides. One showed the Aristotelian system of the universe and another the Copernican system. Two were equipped with cog-wheels and the planets actually revolved round the sun with their satellites.

In concluding her address, Dr. Douglas said that the repercussions on philosophy caused by "De Revolutionibus" had been far reaching. This was realized more fully by Galileo than by Copernicus himself. As the geocentric outlook was discarded by the scientist, the anthropocentric viewpoint of philosophy was bound to be affected. Man no longer seemed obviously of prime importance. To-day our first deduction from a survey of the physical universe is not of the importance but of the apparent insignificance of man. If man is of importance, we realize, thinking of great men such as Copernicus, that it is not for physical but for intellectual and spiritual reasons.

Following the address Dr. Keys called upon Dr. Francis to speak. Dr. Francis had brought with him two books from the William Osler Library. One was a first edition of "De Revolutionibus Orbium Celestium." The binding of the book, however, was seventeenth century, and when it was rebound the margins had been made narrower, for some of the handwritten notes had been cut off. The book also contained marginal notes by Dr. Osler which gave it a particular value. Dr. Francis had many interesting comments to make. (For notes by Dr. Francis see Plate V, facing page 129 of the April issue. The text of Dr. Douglas's lecture will be found in *Queen's Quarterly* for June 1943. —*Editor*)

The other book, a first edition of "De Humani Corporis Fabrica," Vesalius's great book on anatomy, had been selected by Dr. Francis because, published in the same year, 1543, it with "De Revolutionibus" marked the beginning of modern science.

Dr. Brzezinski, the Polish consul, said a few words, expressing his pleasure at being present.

Mr. D. P. Gillmor, president of the Montreal Centre, tendered a vote of thanks to Dr. Douglas for her excellent address.

ISABEL K. WILLIAMSON, *Recording Secretary.*

AT OTTAWA

April 9, 1943.—An open meeting of the Ottawa Centre was held at the Victoria Memorial Museum Hall. A large and attentive audience of several hundred nearly filled the great lecture room. Dr. T. L. Tanton, President of the Ottawa Centre, was chairman.

Dr. Tanton introduced the speaker of the evening, Dr. A. Vibert Douglas, Dean of Women of Queen's University, President of the R.A.S.C.

Dr. Douglas's subject was "Copernicus (1473-1543) Commemoration Lecture." First she described briefly the conditions of society and the state of learning in his times. Both were very unsettled, especially in Poland, the homeland of Copernicus. She then gave an outline of the life of Copernicus,

showing him as a man of many parts, but it was in the realm of mathematics and astronomy that he showed greatest originality and genius. He gave us that heliocentric theory of the universe which was so vastly nearer the truth than the old geocentric theory. Dr. Douglas carefully pointed out how great a revolution in thought this was, and how hard it proved for man to admit himself no longer central in the scheme of things as he had been wont to believe. Dr. Douglas then brought the picture up to date by describing the important discoveries since the time of Copernicus which have given us the much greater knowledge we have to-day.

The lecture was illustrated with excellent slides, some of which were ingenious mechanisms with a train of wheels which made it possible to show the solar system in motion.

This lecture was given as part of the commemoration of Copernicus which is to be held so widely this year, the four-hundredth since his death, especially at centres of learning on this continent.

The Hon. Victor Podoski, Minister of Poland, cordially thanked the speaker. He remarked that Copernicus, who was a Pole of whom his countrymen were most proud, was also much more: he was one of those men whose achievements transcend boundaries and in whom was the real hope for human advancement.

F. W. MATLEY, *Secretary*.

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1890-1943

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For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 800 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

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